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[0001] WIRELESS COUPLING OF STACKED DIES WITHIN SYSTEM IN PACKAGE

[0002] CROSS REFERENCE TO RELATED APPLICATION(S)

[0003] This application claims priority from U.S. Provisional Patent Application No. 60/507,971, filed October 2, 2003, which is incorporated herein by reference.

[0004] FIELD OF INVENTION

[0005] The present invention relates to semiconductor packaging and to stacked semiconductors. More particularly the invention relates to the interconnection of semiconductor dies in a stacked relationship, either within a single package or in discreet packages in a stacked or closely adjacent configuration.

[0006] BACKGROUND

[0007] One of the problems with stacked semiconductor dies is a requirement for interconnection. Typically such interconnection is achieved by wirebonding, because techniques used for direct bondpad-to-leadframe connections, such as flip chip and bump connections, are difficult to achieve in the situation of multiple dies. In addition, if a multi-chip module (MCM) is to be pre-characterized and tested, dies which are inoperative must be disconnected and then re-connected to the package substrate. In addition, the transfer of data at high speeds creates problems with respect to lead wires, in that the lead wires tend to have significant inductance, particularly at high frequencies. Accordingly, it is desired to provide a multi-chip module (MCM) in which communication is effected in a manner which bypasses the requirement for lead wires.

[0008] Another problem with stacked dies is that, if it is desired to communicate between the dies, then some form of a connection must be made between the dies.

There are two ways to accomplish this: 1) direct interconnection from one die to another die; and 2) connection from one die to a lead frame or a connection on a package substrate and a second connection from the lead frame or substrate to a second die. In the case of a direct connection, it becomes necessary to provide wirebonding from die to die. In the case of an interconnection through the lead frame or substrate, a double connection is required, thereby a creating a potential for more signal loss. Accordingly, it is desired to provide a signal communications system for semiconductors in which multiple semiconductors in a vertically spaced relationship or in a closely-spaced relationship are able to communicate. It is further desired to reduce the number of internal connections for a semiconductor package, and if possible, not greatly exceed the lead count for the package.

[0009] SUMMARY

[0010] In accordance with the present invention, semiconductor dies which are closely positioned are provided with an RF link in order to effect communications between the dies. In the case of stacked semiconductor dies, in which multiple dies are stacked within a single package, RF communication is established between the dies. This permits communications between the dies in the package to be effected without wirebond connections between the dies, or with a reduced number of wirebond connections between dies.

[0011] In another aspect of the invention, multiple dies in a single package are provided with RF transceivers and communications between the dies are effected through RF links through the transceivers. This configuration can be used for either stacked or planar multi-chip modules, thereby reducing the number of physical signal connections between dies.

[0012] In yet another aspect of the invention, the RF transceivers are used to establish links between dies which are either within a single package or within separate packages. This enables the use of multiple semiconductor dies in a manner which reduces a necessity for physical connections between the dies.

[0013] BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Figure 1 is a side view of a stacked semiconductor package, schematically showing the use of RF transceivers to establish communication links between stacked dies.

[0015] Figure 2 is a top view of a multi chip module, schematically showing the use of RF transceivers to establish communications links between semiconductor dies.

[0016] DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Figure 1 is a side view of a multi-chip module 10 in which a plurality of dies 11_1, 11_2, 11_3, 11_N are shown in a stacked relationship. The bottom of the die 11_N is shown as mounted on a package substrate 21. As depicted, the specific number, N, of dies 11_1, 11_2, 11_3, 11_N can vary. Although, the stacking of the dies 11_1, 11_2, 11_3, 11_N is shown as precluding mounting more than one of the dies 11_1, 11_2, 11_3, 11_N directly on the same package substrate 21. In other embodiments, multiple dies can be stacked directly on the substrate 21. A plurality of wirebond connections 31_1, 31_2, 31_3, 31_N are shown, in which the stacked dies 11_1, 11_2, 11_3, 11_N are wire connected to the package substrate 21. The wirebond connections 31_1, 31_2, 31_3, 31_N are established at some point during assembly, so that if for some reason one of the dies 11_1, 11_2, 11_3, 11_N is changed, the wirebonding must be re-executed.

[0018] Some dies 11_1, 11_3, 11_N include an RF transceiver 41_1, 41_3, 41_N. For simplicity, the transceivers 41_1, 41_3, 41_N are depicted on an opposite side of each die 11_1, 11_2, 11_3, 11_N from the bond pads. In practice, typically, the transceivers 41_1, 41_3, 41_N will be on a surface of each die 11_1, 11_2, 11_3, 11_N adjacent to the bondpads as well as separate from the bondpads. As illustratively shown, not all the dies 11_2 may include RF transceivers.

[0019] The RF transceivers 41_1, 41_3, 41_N are capable of RF communication with closely adjacent transceivers, such as the other transceivers 41_1, 41_3, 41_N on the near-

by dies 11_1, 11_3, 11_N. The transceivers 41_1, 41_3, 41_N include modulator/demodulator circuits, which facilitate communications between the dies 11_1, 11_3, 11_N.

[0020] In the configuration shown, the bottom die 11_N, while equipped with RF transceiver 41_N, is not able to communicate with the package substrate 21 by use of RF transmissions, although in other embodiments the substrate may have the RF transceiver or both may have the transceiver. Conveniently as shown, this die 11_N is mounted adjacent to the substrate 21 and is able to use hardwire connections for communications with the substrate 21. Such hardwire connections can be the wirebond connections 31_1, 31_2, 31_3, 31_N shown, or can be any other convenient form of connection. In the case of the communication between the substrate 21 and the adjacent die 11_N being hardwired connections, the RF transceivers 41_1, 41_3, 41_N are used to establish further communication links with other dies 11_1, 11_3, 11_N.

[0021] Figure 2 is top view of a multi-chip module (MCM), in which a semiconductor package 100 is used to hold a plurality of semiconductor dies 101-113. Each die 101-113 may include an RF transceiver 119. The dies 101-113 are each depicted as mounted directly onto a substrate 121 of the MCM 100, although it is one or more of the dies may be positioned in a stacked arrangement. As a result of the direct mounting of the dies 101-113, it is possible to provide direct connections to the mounting substrate 121, and this direct mounting is used for power connections (such as v_{ss}, v_{cc}). It is also possible to directly connect the signal connections for each individual die 101-113 by use of hardwire techniques. Such connection requires the connection configuration of the dies 101-113 to be established prior to configuring such hardwire connections.

[0022] Unused spaces 131-134 are illustratively depicted in the configuration of the MCM 100. It is possible to provide additional dies in those spaces 131-134. The use of RF transceivers permits the additional dies to communicate with the original set of dies 101-113 for which the module 100 was configured, thereby eliminating a requirement to provide separate configurations for the additional dies. The use of RF connections between the dies allows added flexibility in the interaction facilitating

more flexible hardware designs. Additionally, the flexible hardware design is more readily software configurable, since the RF connections can be more readily changed than traditional hardware connections. In alternate embodiments, the RF transceivers on the dies can be utilized to provide RF links between multi-chip modules or even single chip modules (module sets). Preferably, the RF transceivers have a limited range to maintain a small footprint and low power consumption. Accordingly, typically, the modules are in close proximity. However, by sacrificing the small footprint and low power consumption, these distances between the module sets can be increased.

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